The Influence of Cloud Radiative Effects on Extratropical-Tropical and Inter-basin Teleconnection

Wei-Ting Hsiao[1,2], Yen-Ting Hwang[1*](黃彥婷), Sarah M. Kang[3]

[1]National Taiwan University, Taipei, Taiwan

[2] now at Colorado State University

[3]Ulsan National Institute of Science and Technology, Ulsan, Korea

*ythwang@ntu.edu.tw

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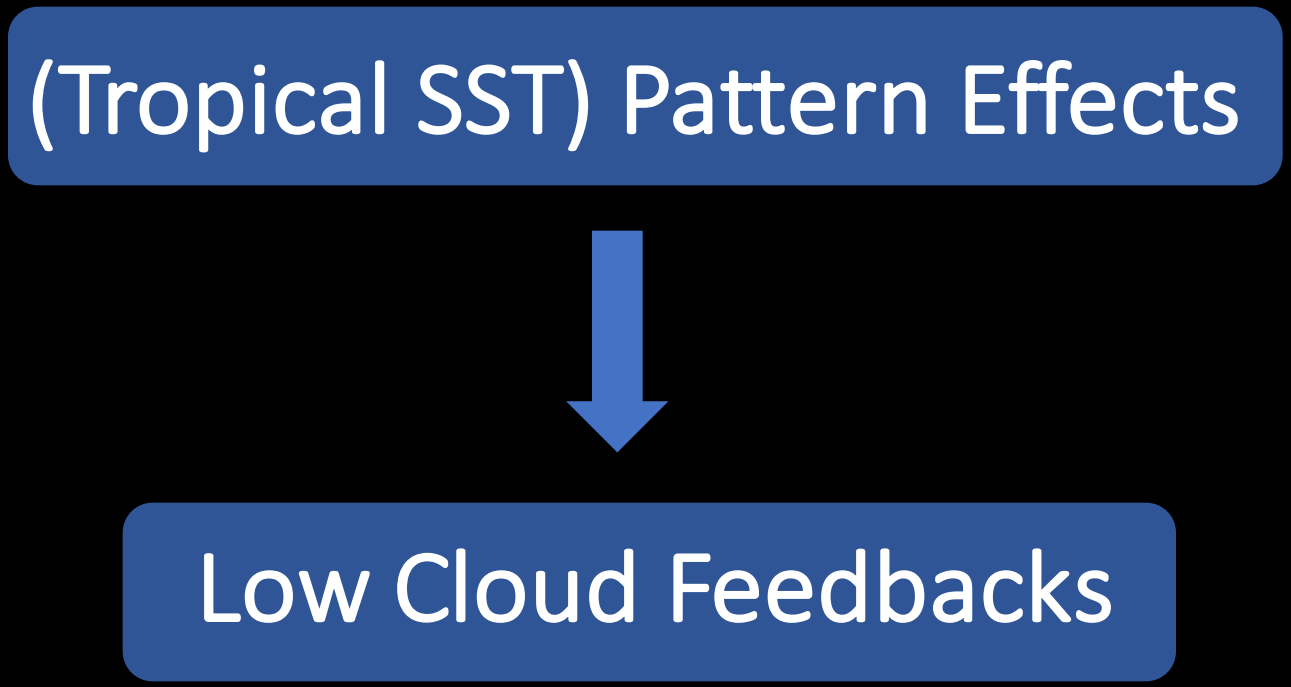
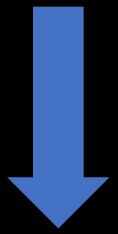

(Tropical SST) Pattern Effects
Low Cloud Feedbacks

Extratropical Influence

1. How does tropical SST pattern respond to extratropical forcings?

(Tropical SST) Pattern Effects



Low Cloud Feedbacks

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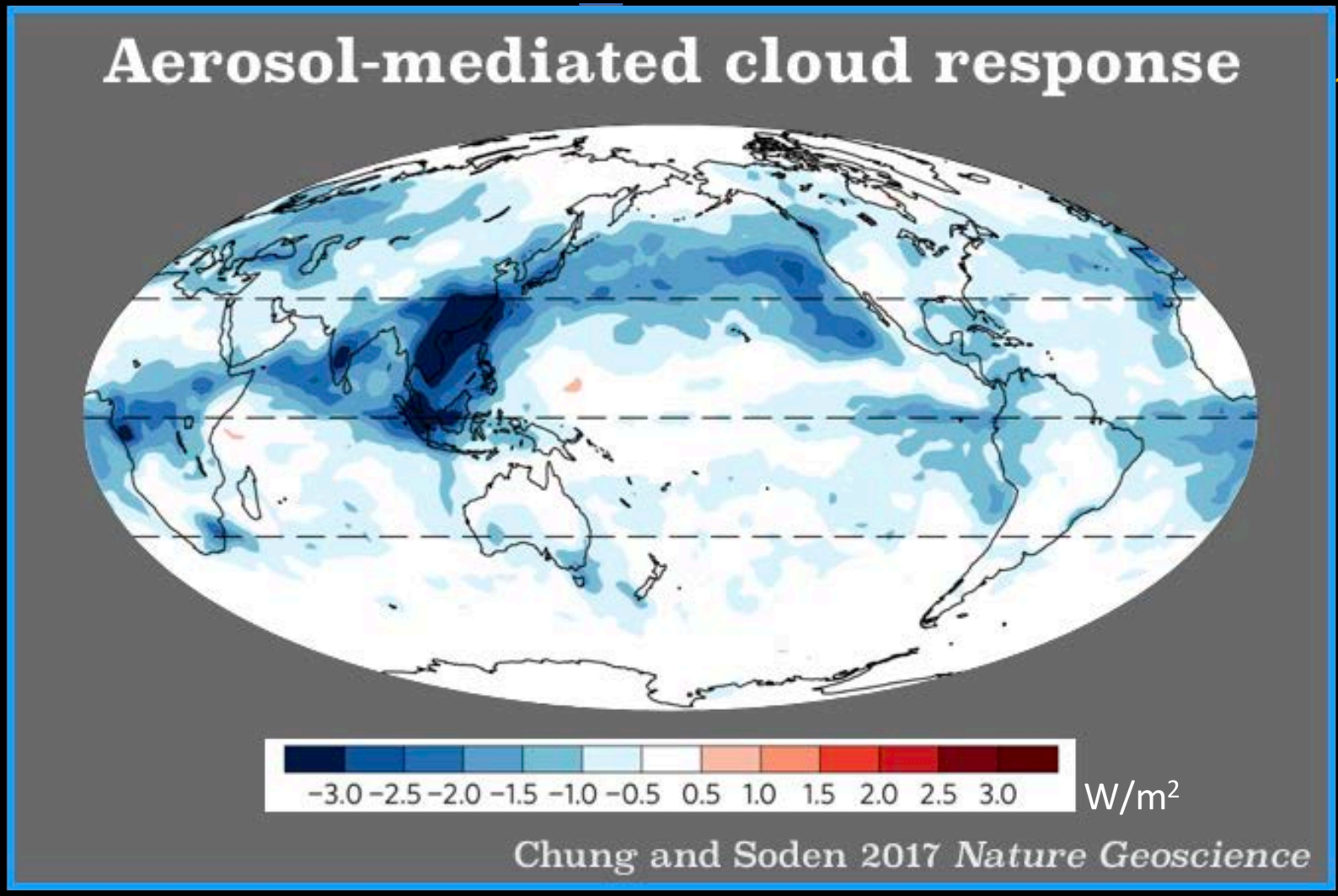

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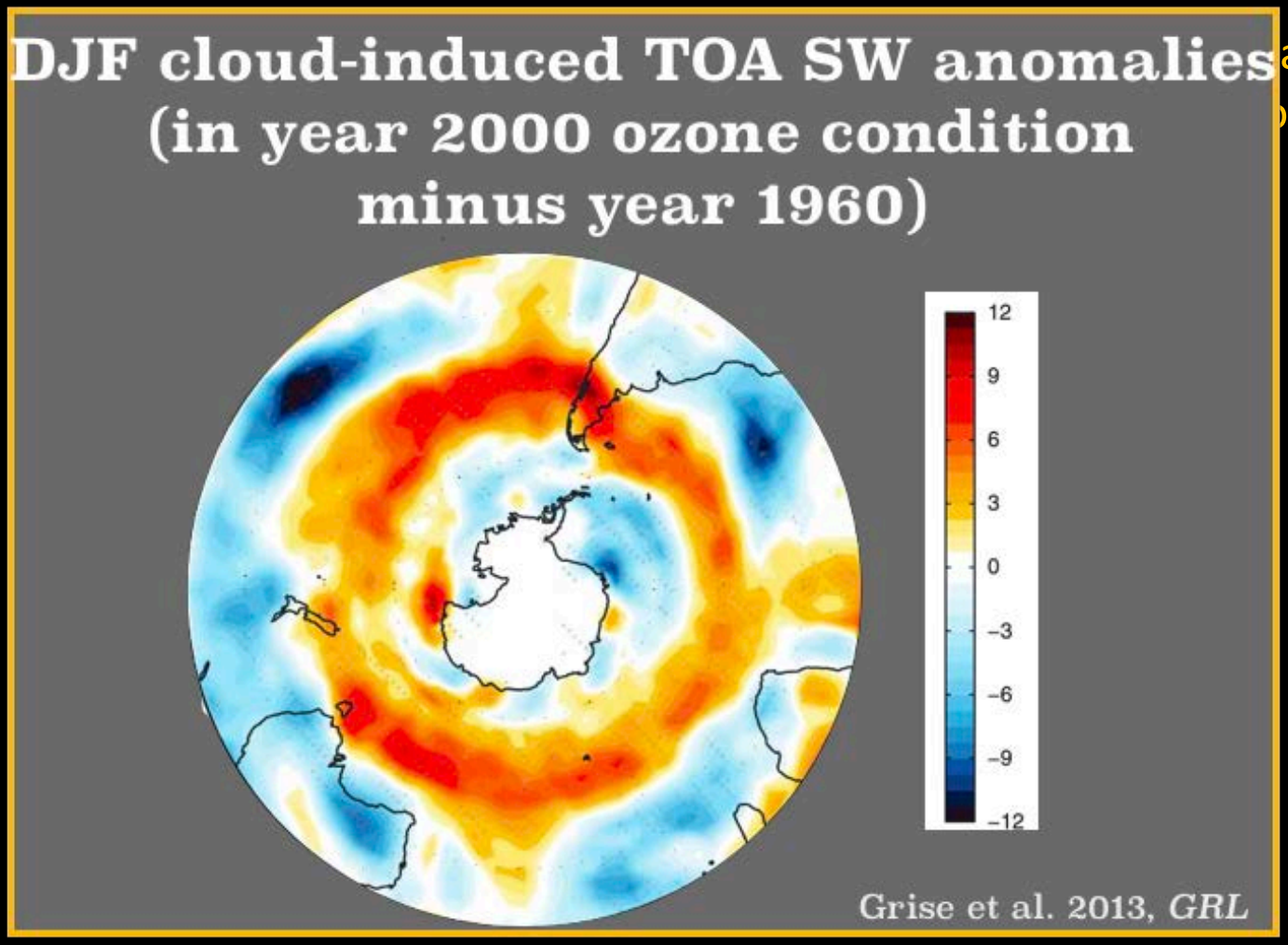

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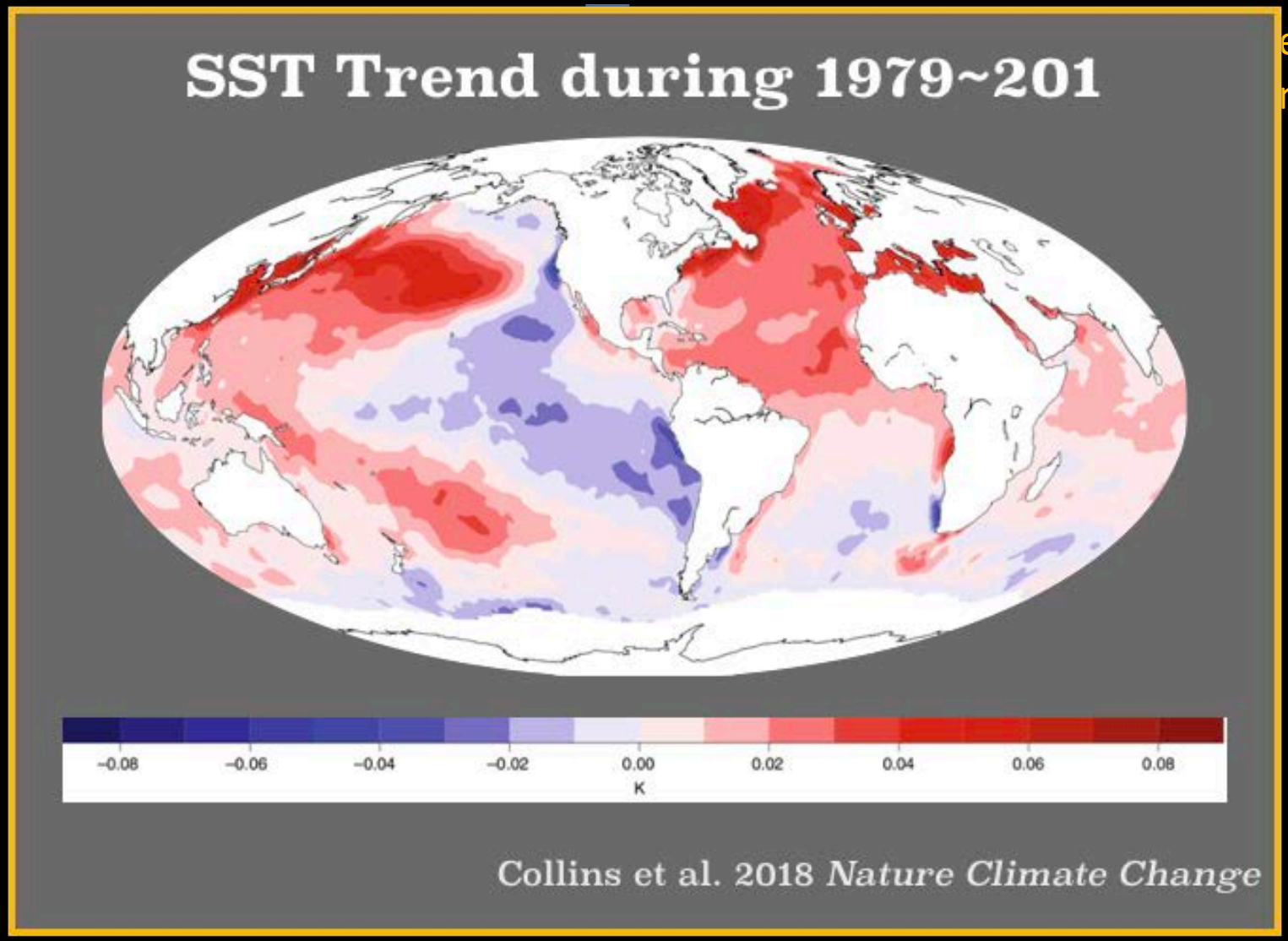

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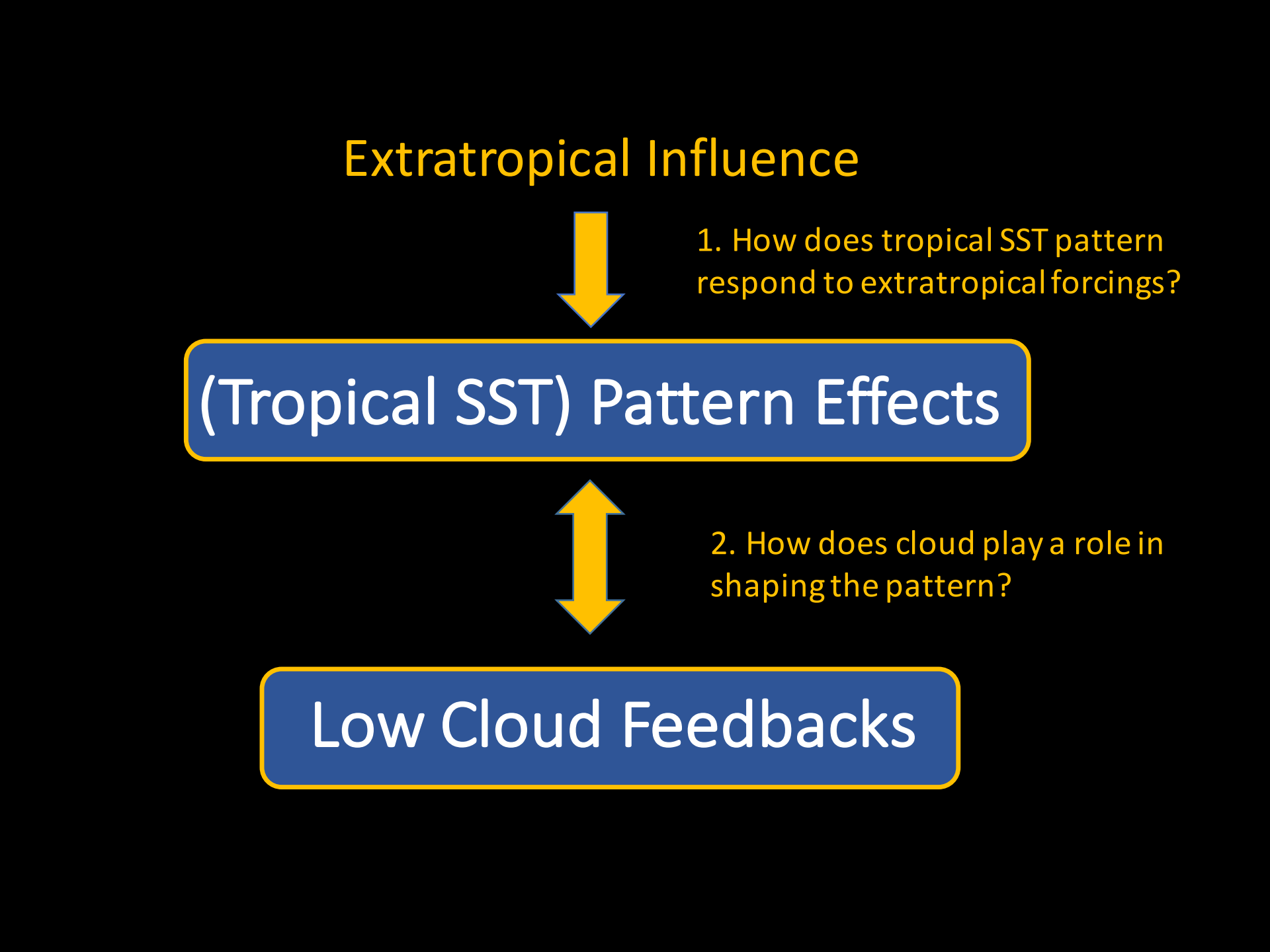
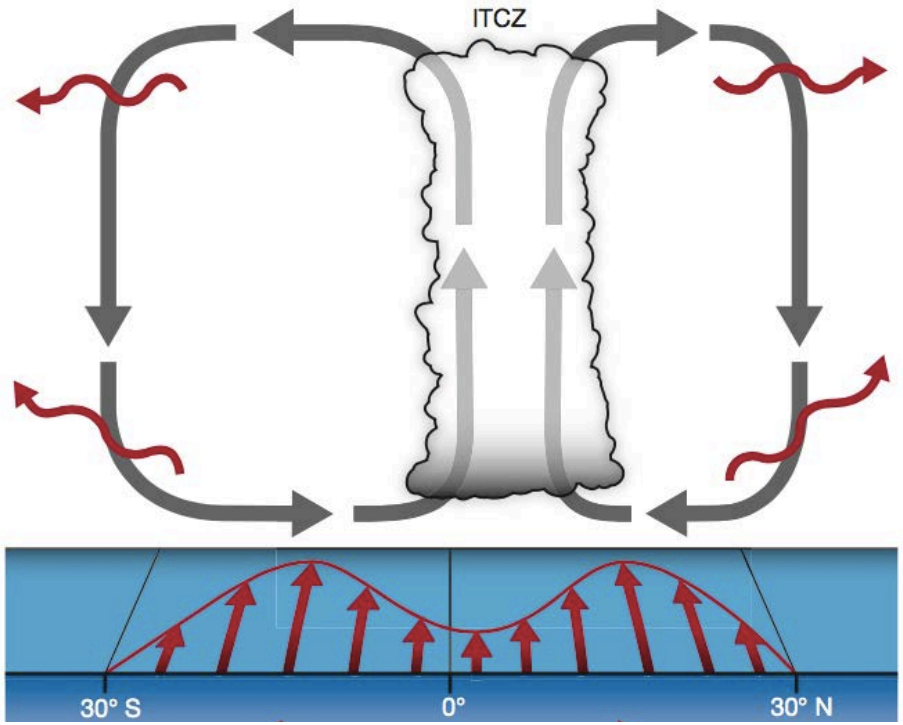

Extratropical Influence
1. How does tropical SST pattern respond to extratropical forcings?
(Tropical SST) Pattern Effects
2. How does cloud play a role in shaping the pattern?
Low Cloud Feedbacks

Introduction

Energetic Framework

"Energy equator tends to move to the warmer hemisphere."

It provides a zonal-mean predictability.



Schneider et al. 2014

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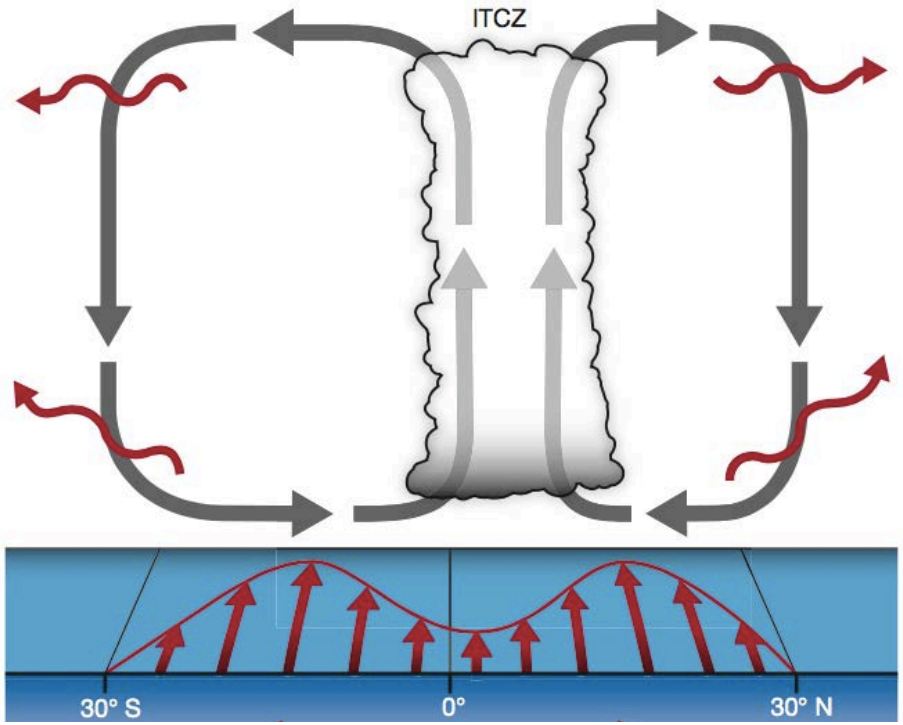
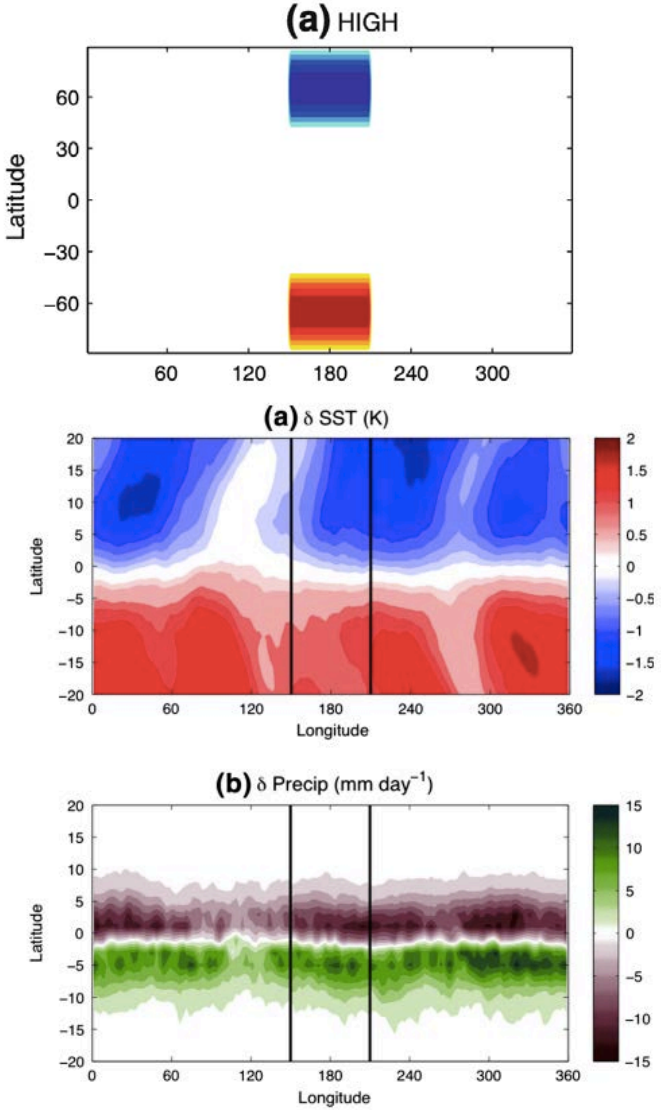


Schneider et al. 2014

Zonal Homogenization

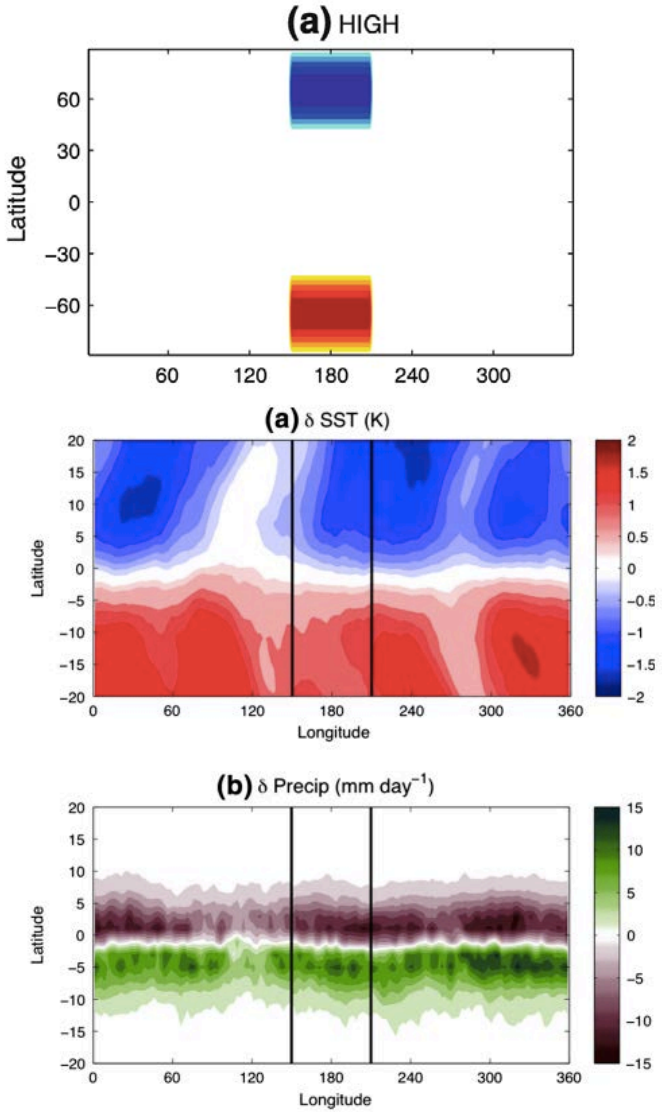


Kang et al. 2014, 2018

Introduction

Zonal Homogenization

What about in more realistic simulations?

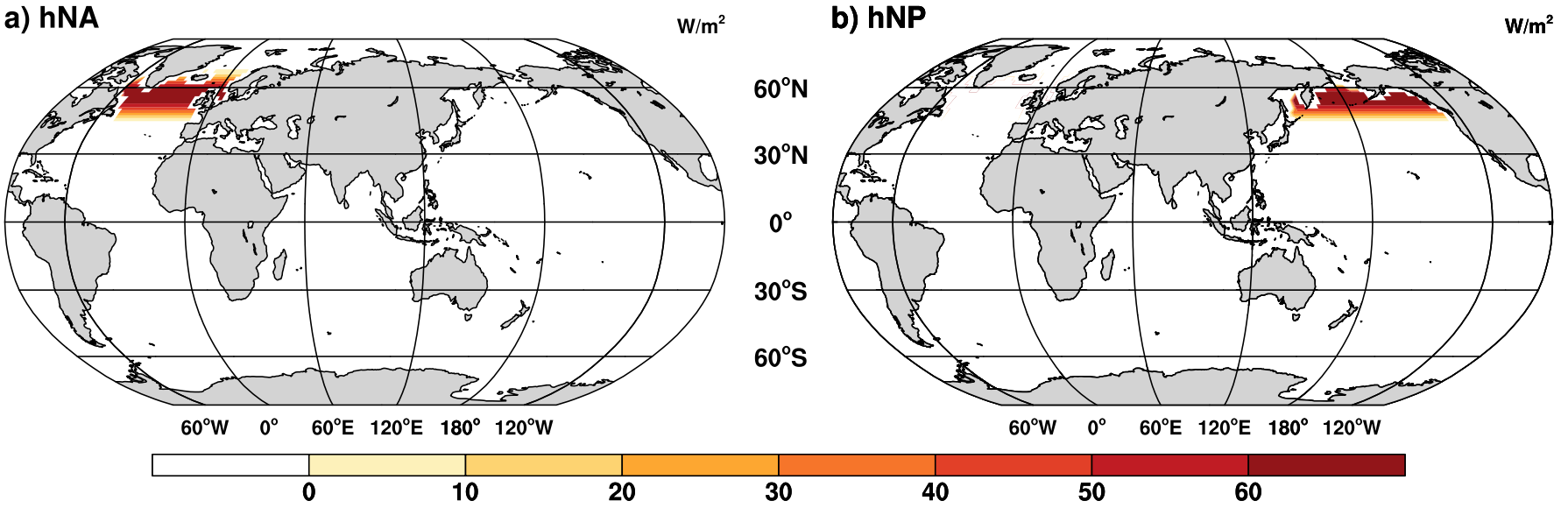


Kang et al. 2014, 2018

Experimental Setting

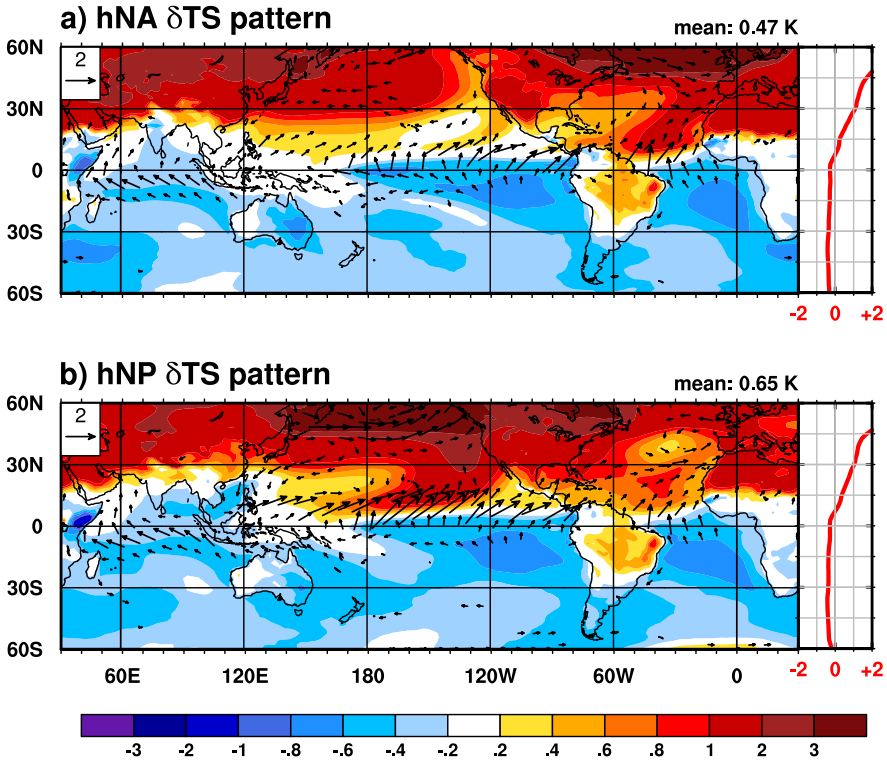
Model: CESM 1.2.0
Setting: 50-m deep slab ocean
Resolution: 1.9°x2.5°
Forcing: +0.41 PW

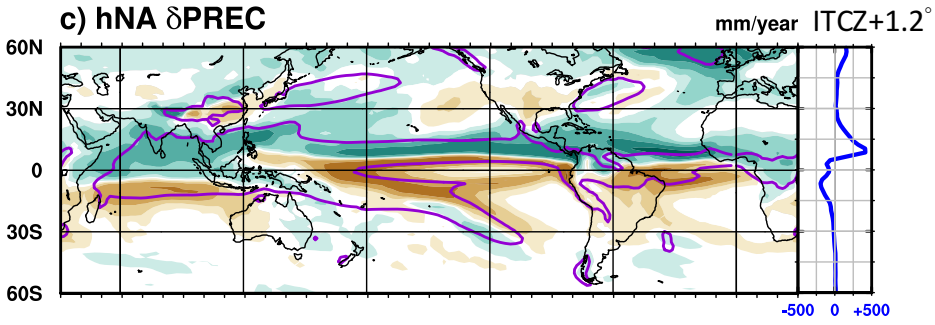
case name	*#time*
CTRL	45 yrs
hNA	#36-#65 (30yrs)
hNP	#36-#65 (30yrs)



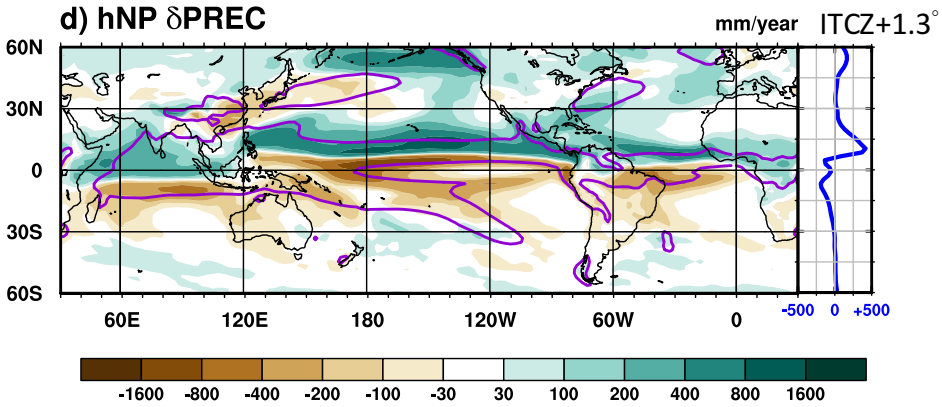
Similar responses in the two exps.

Zonal mean:
Northward shifting of ITCZ





corr: 0.86



corr: 0.87

purple: > 1600 mm/yr

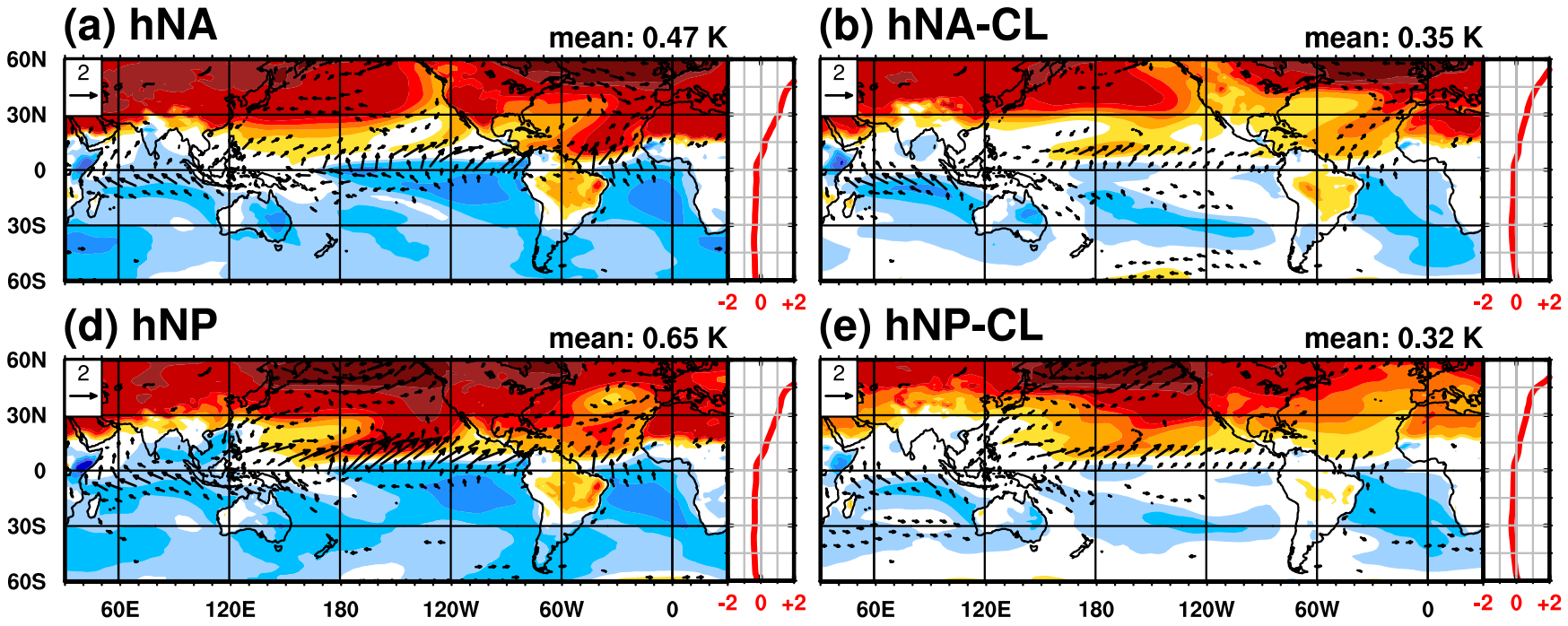
Spatial pattern:

> consistent with the theory of zonal homogenization

> similar La Niña-like responses

Understanding the role of cloud through cloud-locking exps.

(Ceppi and Shepherd 2017, Middlemas et al. 2019)



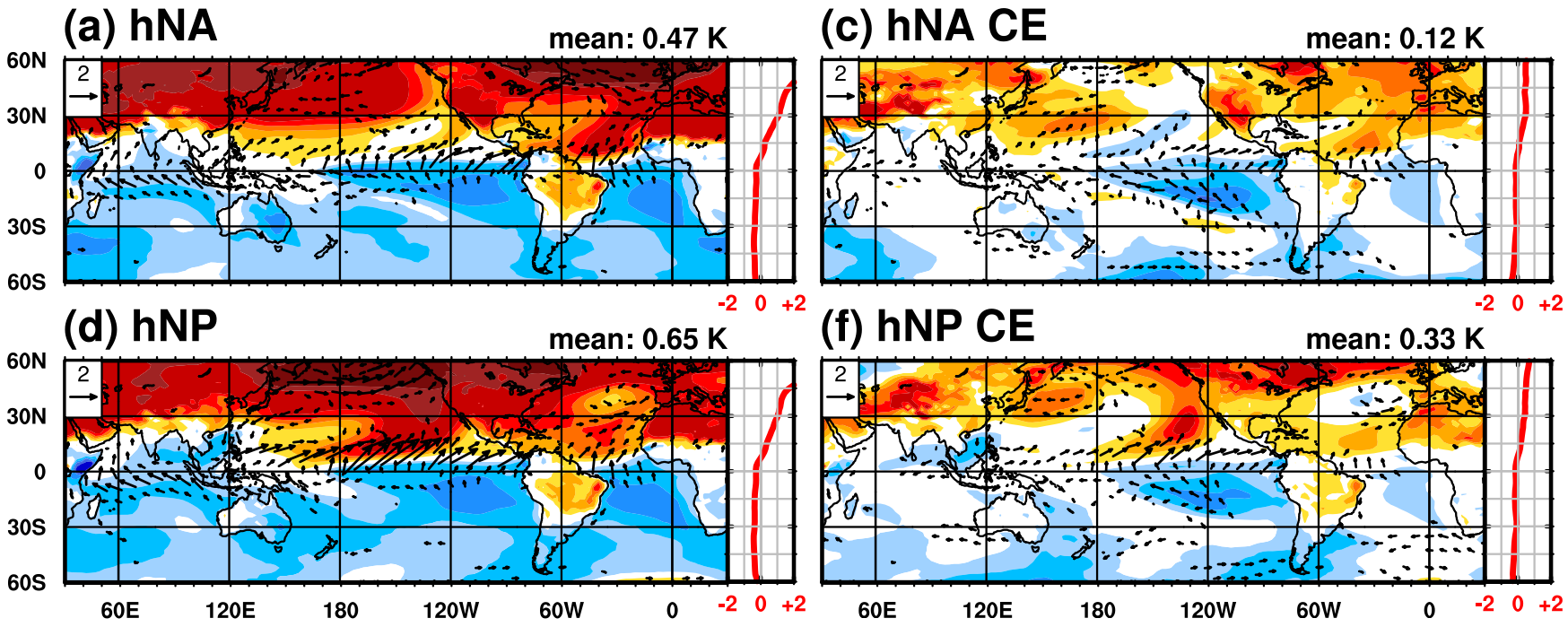
Cloud-Locking Responses:

> Weakened meridional asymmetry (68% of the original ΔSST_{NS})

> Lack of robust zonal asymmetry (only 16% of the original ΔSST_{WE})

Cloud effect (CE)

Cloud Effect = Response (interactive cloud) – Response (locked cloud)



Cloud Effect (hNA):

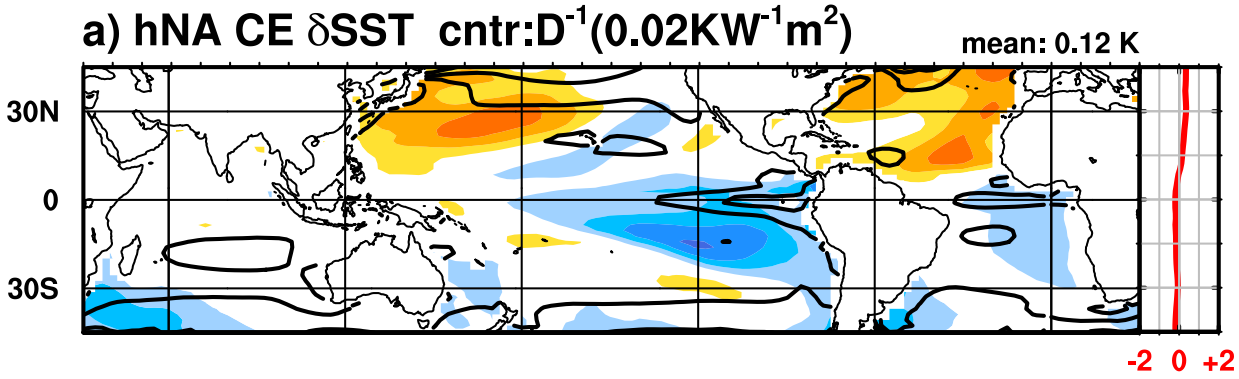
> Strengthens meridional asymmetry (contributes 32% of the ΔSST_{NS})

> Contributes +30% of ITCZ shifting

> Induces zonal asymmetry (contributes 84% of the ΔSST_{WE})

Cloud effect: WES feedback triggered by cloud

See Zhang and Li (2014), Hwang et al. (2017) for the mixed layer budget decomposition



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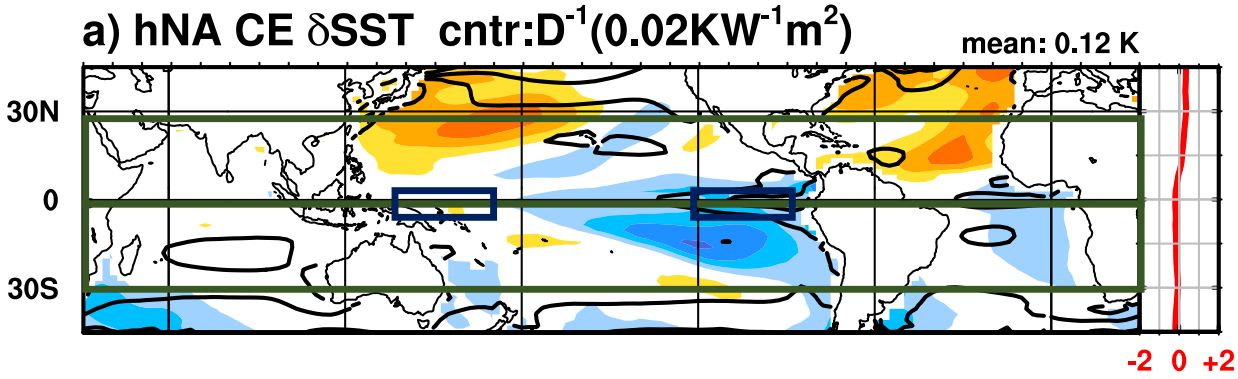

ΔSST_{NS}: $+0.16\ K$

ΔSST_{WE}: $+0.51\ K$

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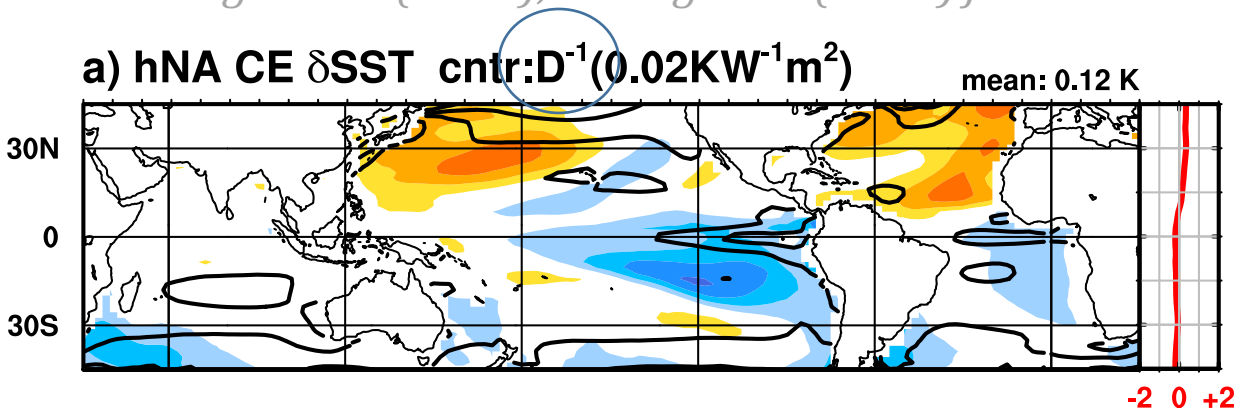

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Mixed layer energy budget

$$\rho C_p H \frac{\partial T}{\partial t} = Q'_{sw} + Q'_{lw} + Q'_{lh} + Q'_{sh} + O'$$

Bulk formula

$$Q'_E = L_v C_E \rho_a W (q_s - q_a) = L_v C_E \rho_a W [q_s(T) - RH \bullet q_s(T + \Delta T)],$$

$$Q'_{lh} \cong -Q'_E = -\frac{\partial Q_E}{\partial T} T' - \frac{\partial Q_E}{\partial W} W' - \frac{\partial Q_E}{\partial RH} RH' - \frac{\partial Q_E}{\partial \Delta T} \Delta T',$$

A diagnostic equation for SST

$$T' = \frac{Q'_{sw,cld} + Q'_{sw,clr} + Q'_{lw} - Q'_{E,W} - Q'_{E,RH} - Q'_{E,\Delta T} + Q'_{sh}}{\alpha \overline{Q_E}}$$

D

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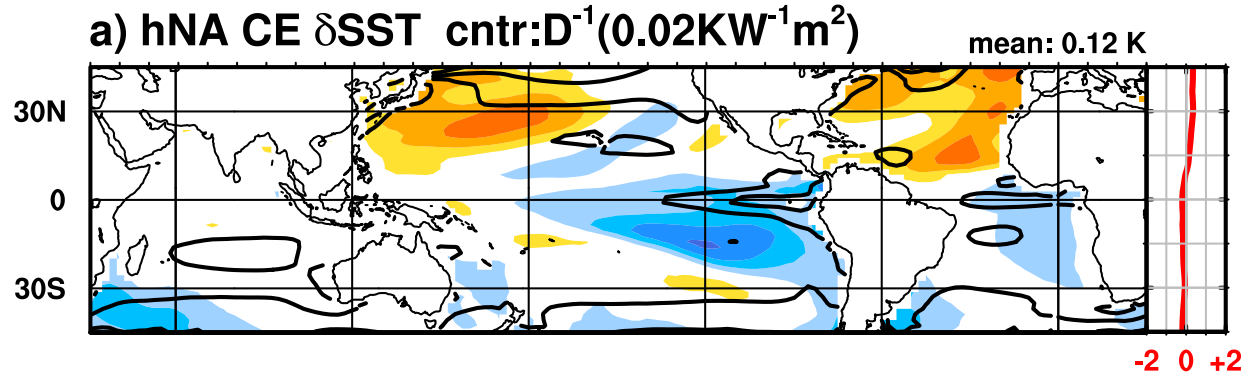

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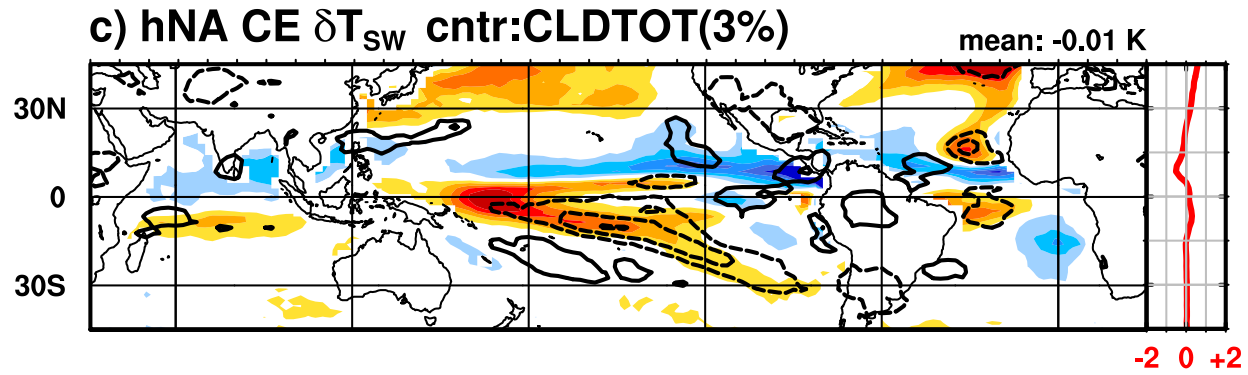
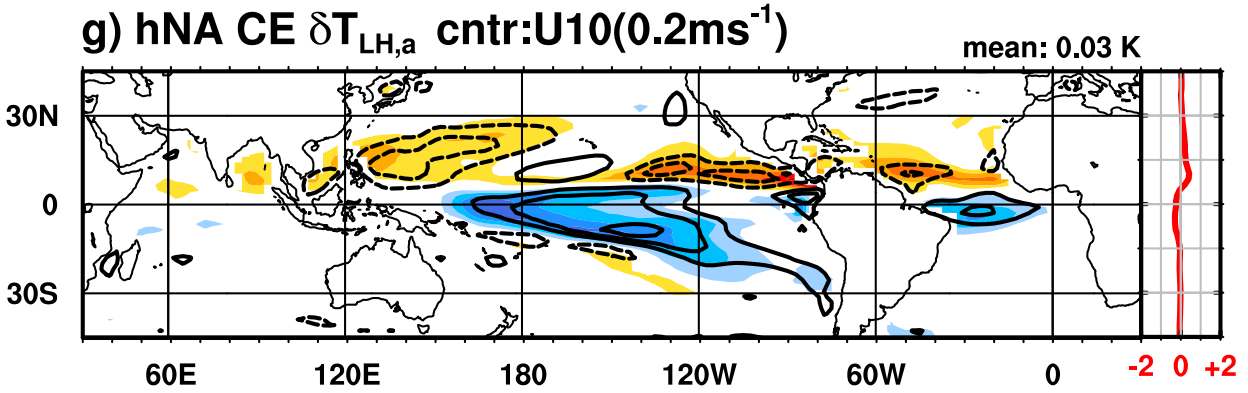


ΔSST_{NS}: $-0.26\ K$

ΔSST_{WE}: $+0.70\ K$



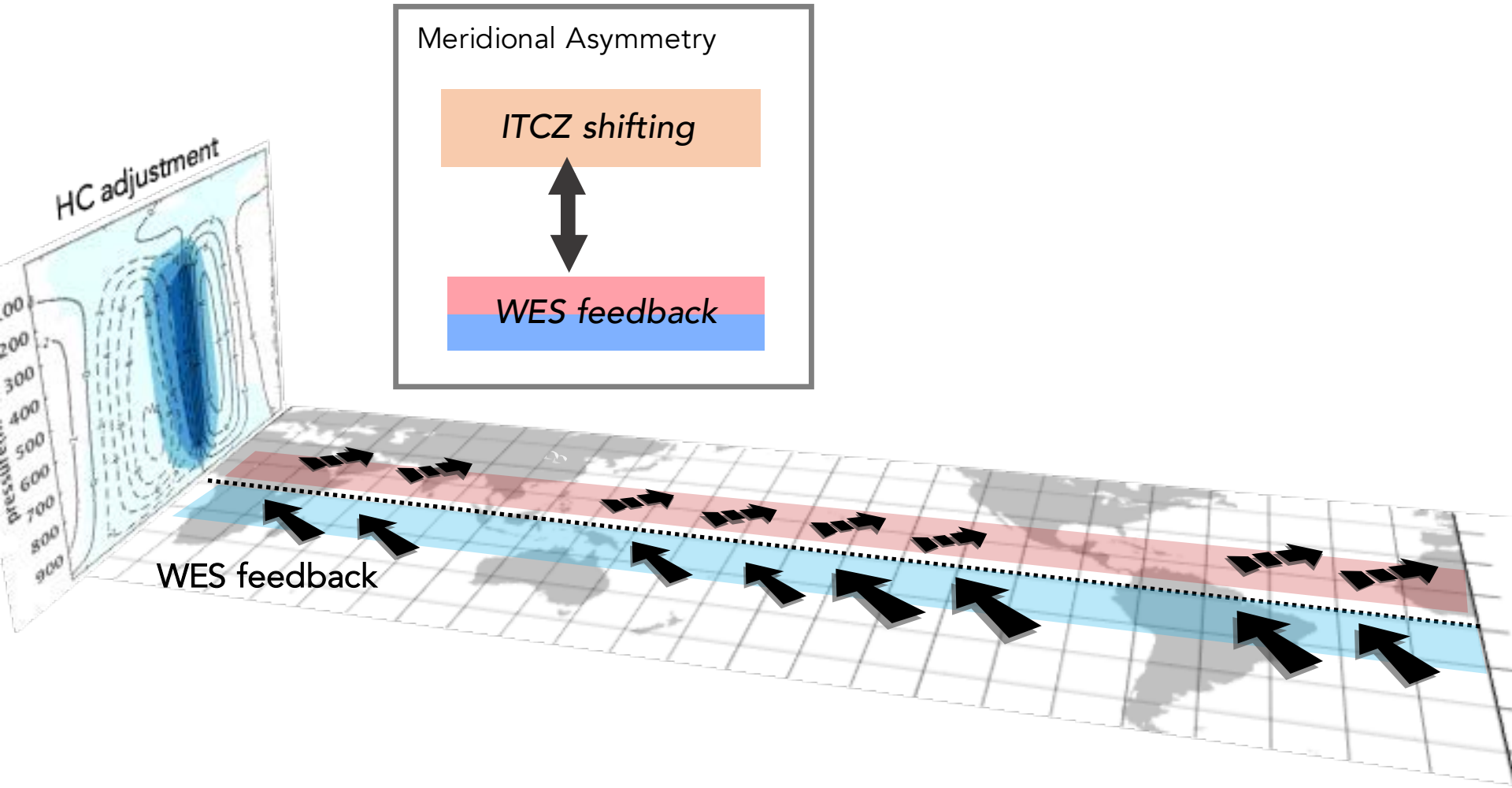
ΔSST_{NS}: $+0.28\ K$

ΔSST_{WE}: $-0.20\ K$

Mechanism

Linking meridional and zonal SST gradient

Chiang et al. 2008, Fedorov et al. 2015, Li et al. 2013



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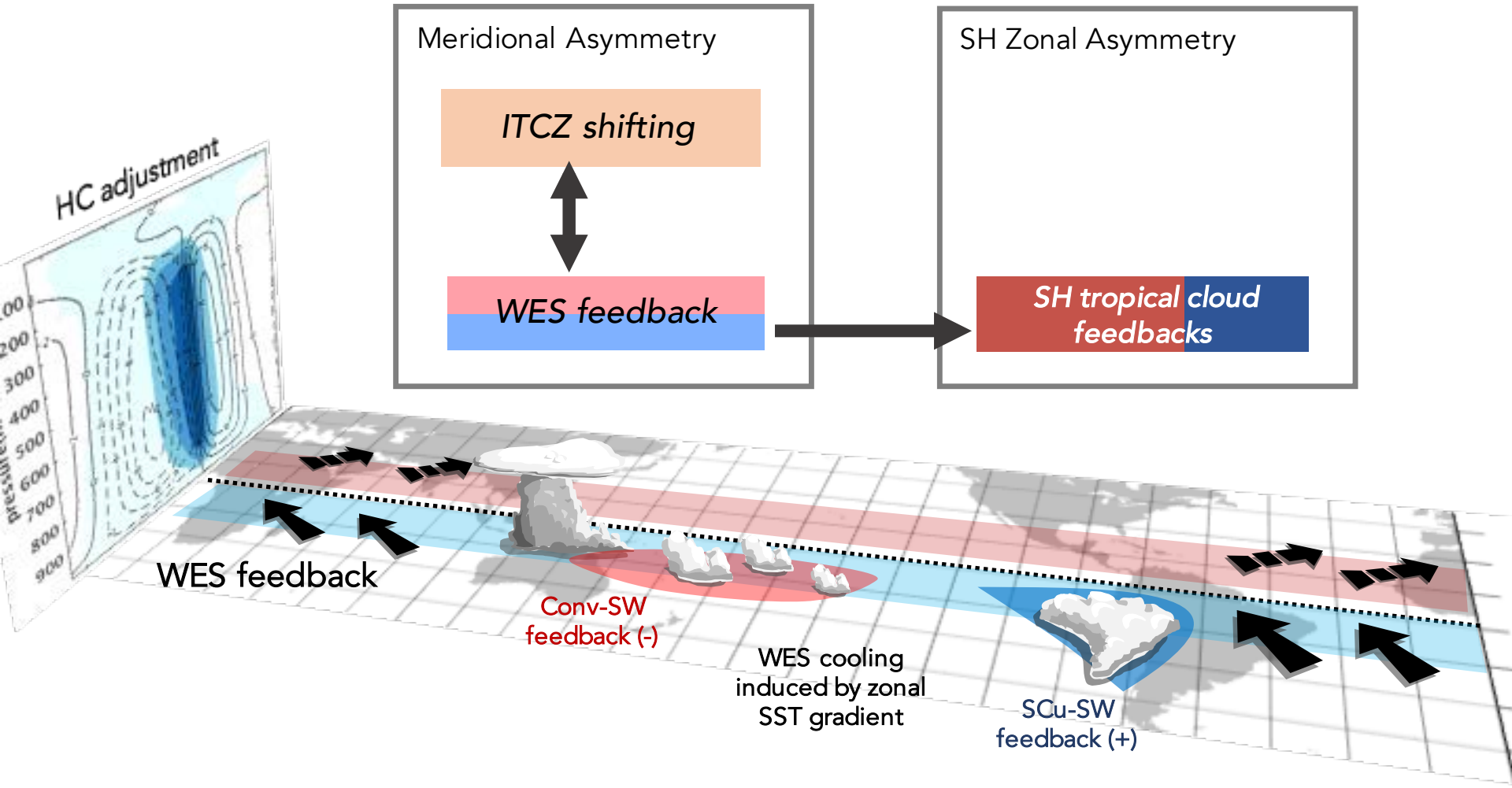

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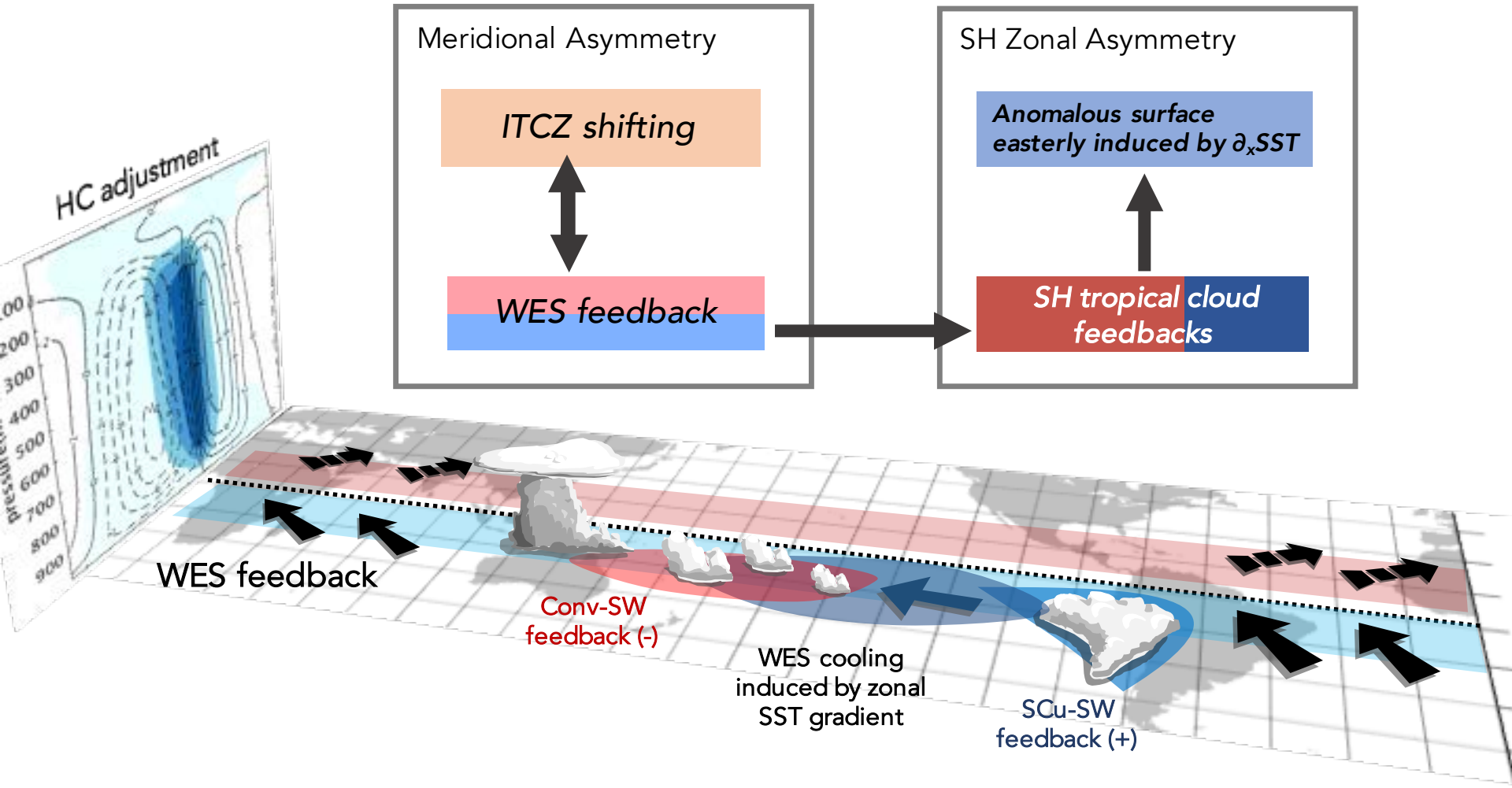

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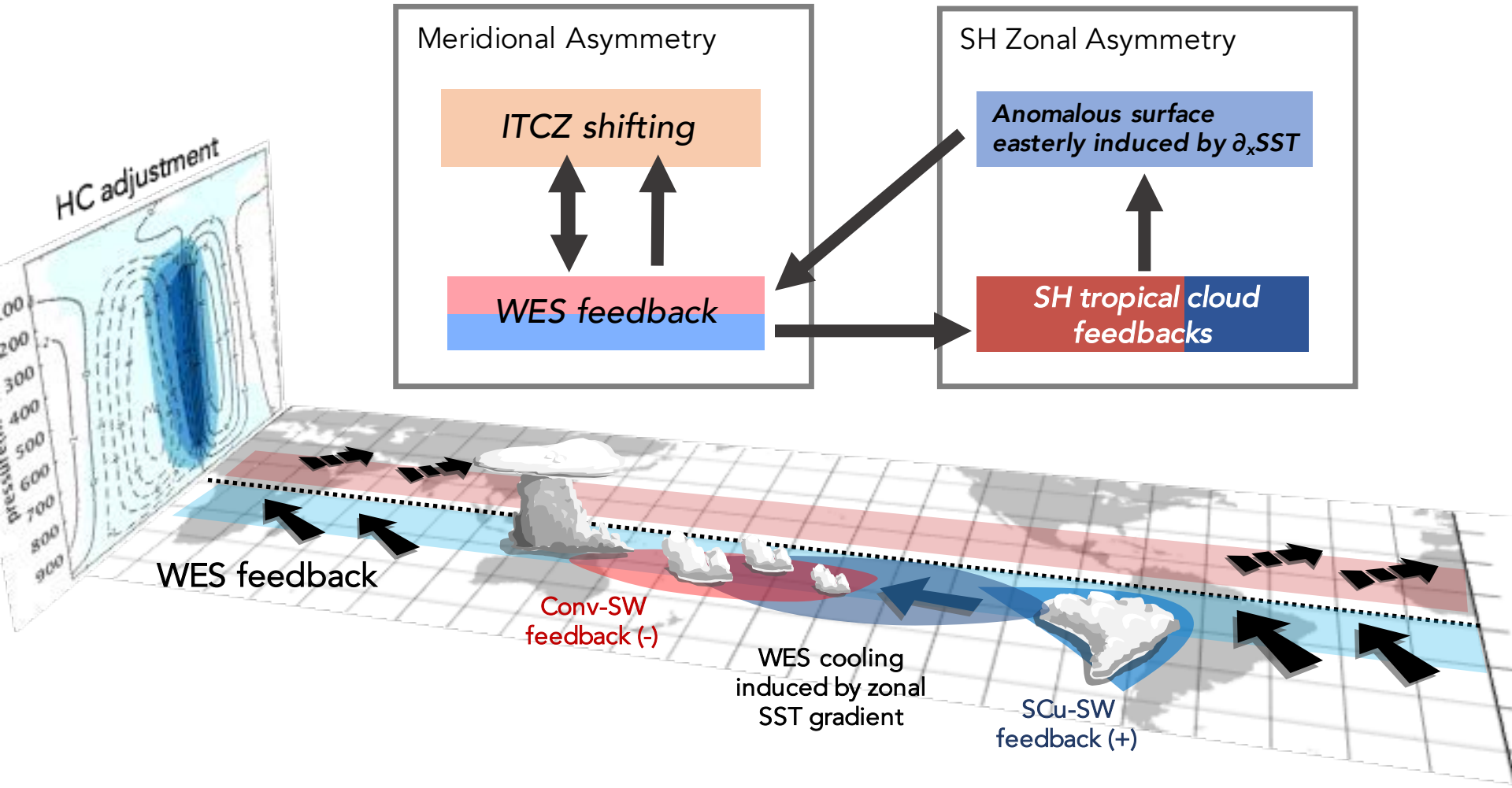

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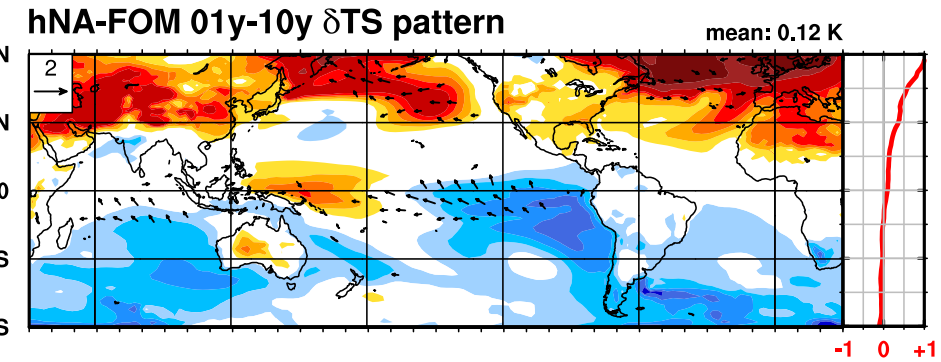
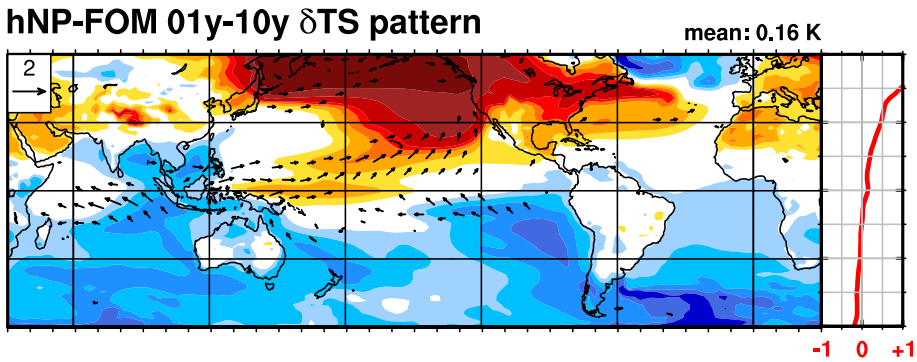
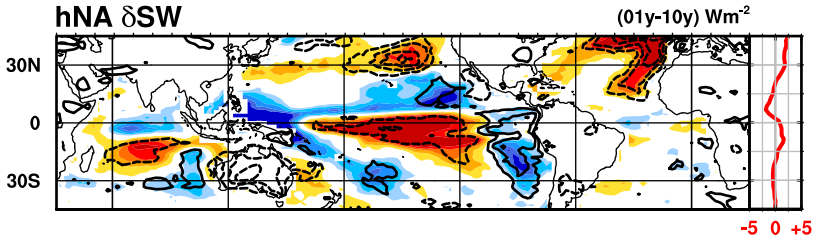
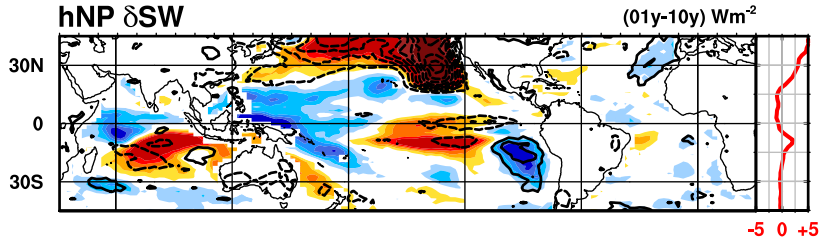
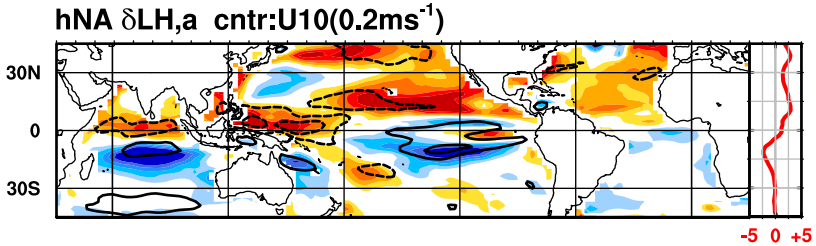
Would ocean dynamics change the pattern?

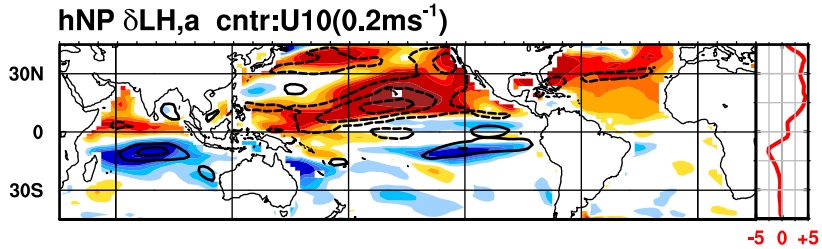


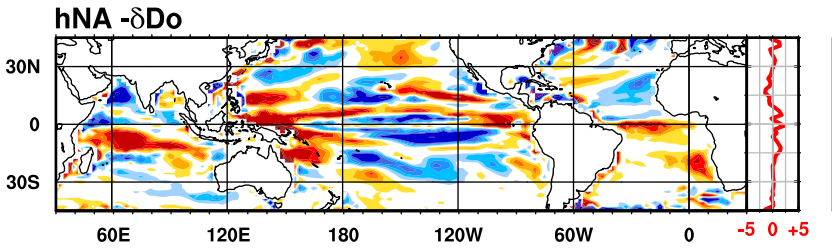


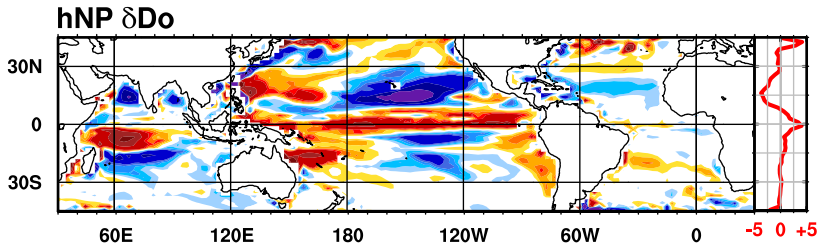












Note: scale of colorbar*0.5

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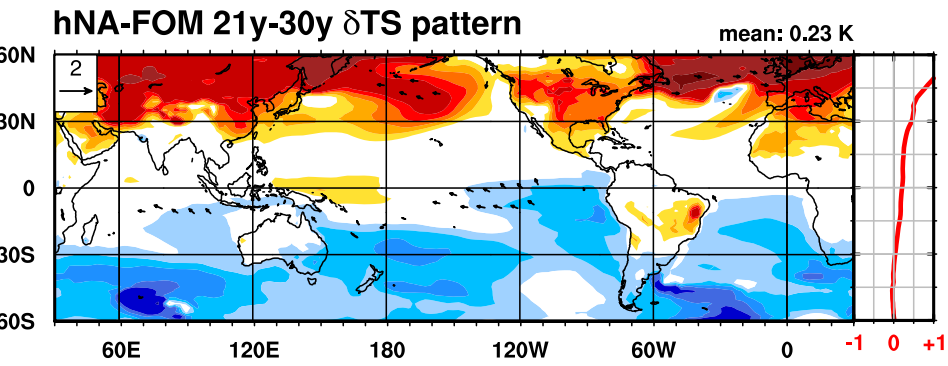
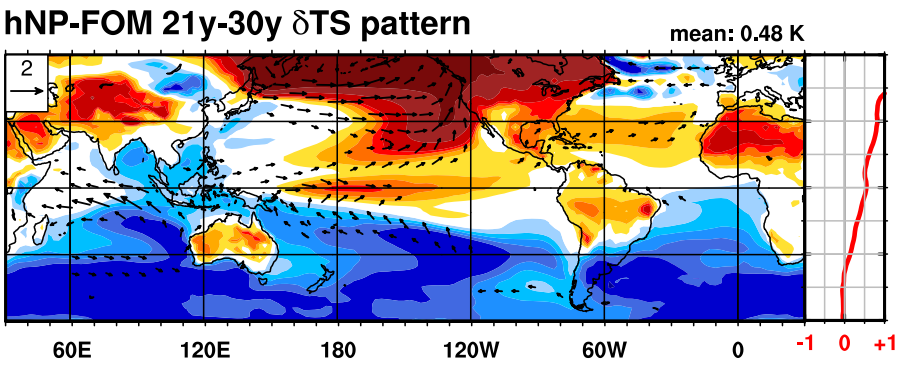
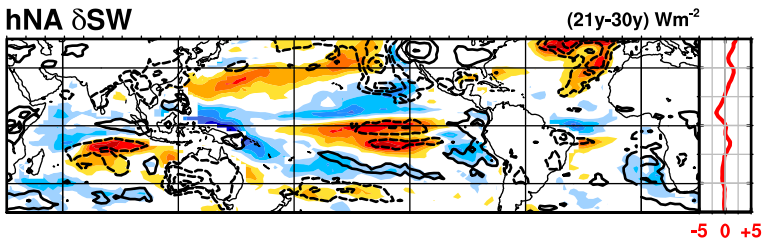
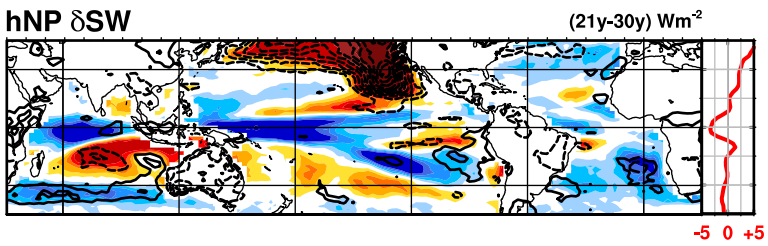
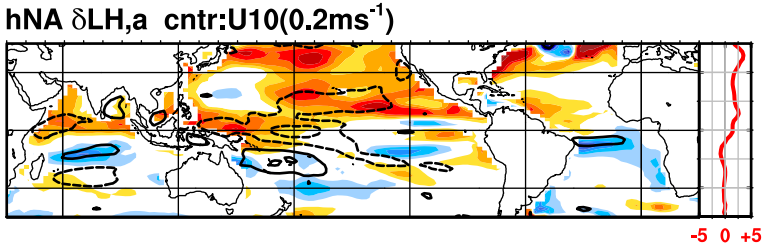
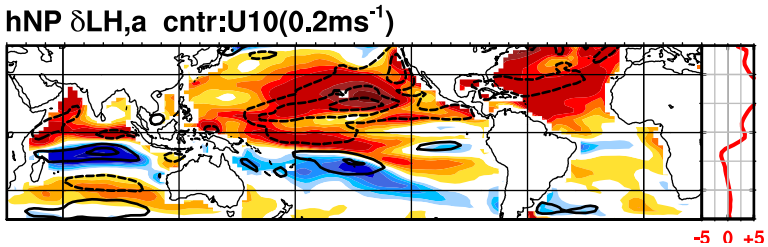


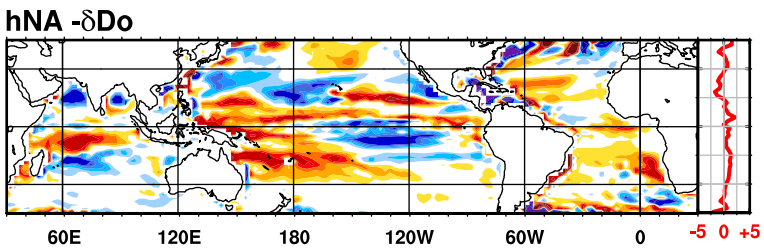


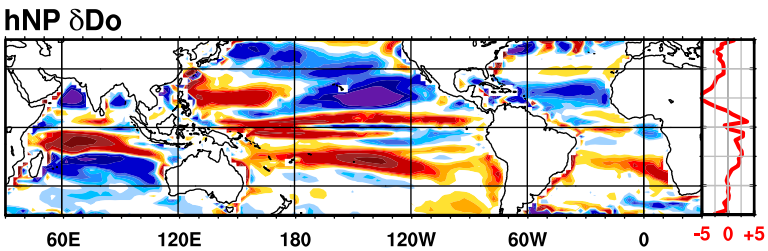








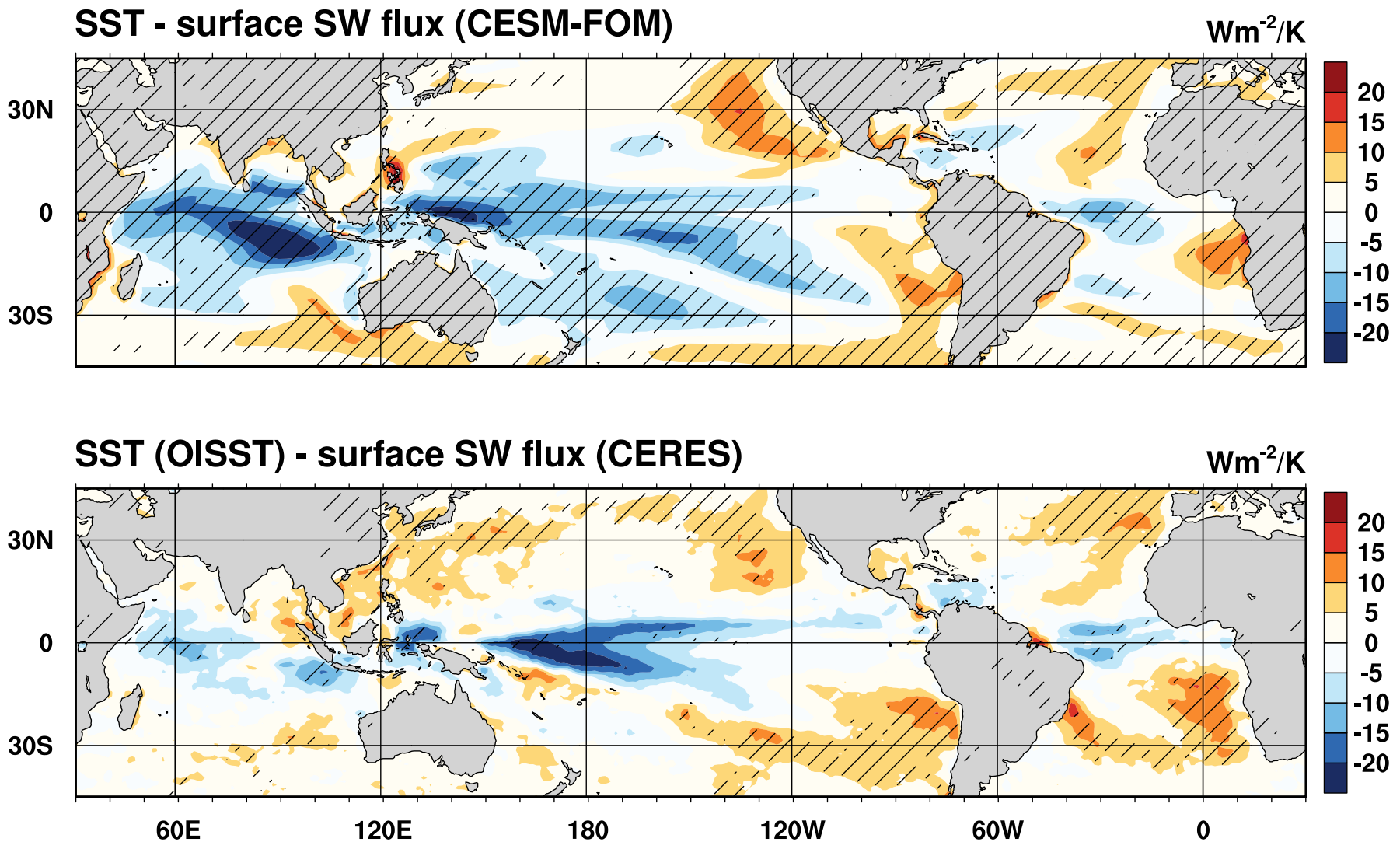




Note: scale of colorbar*0.5

Cloud biases?

Linear Regression Maps (using monthly data removing seasonal cycle)



Questions?

a WES-cloud chained process

NH ext. heating

Kang et al. (2008)

the energetic framework

ITCZ shifting

Xie and Philander (1994)

WES feedback

+

Surface wind anomaly induced by ∂_xSST

SH tropical cloud feedbacks

Conv-SW (-)

SCu-SW (+)

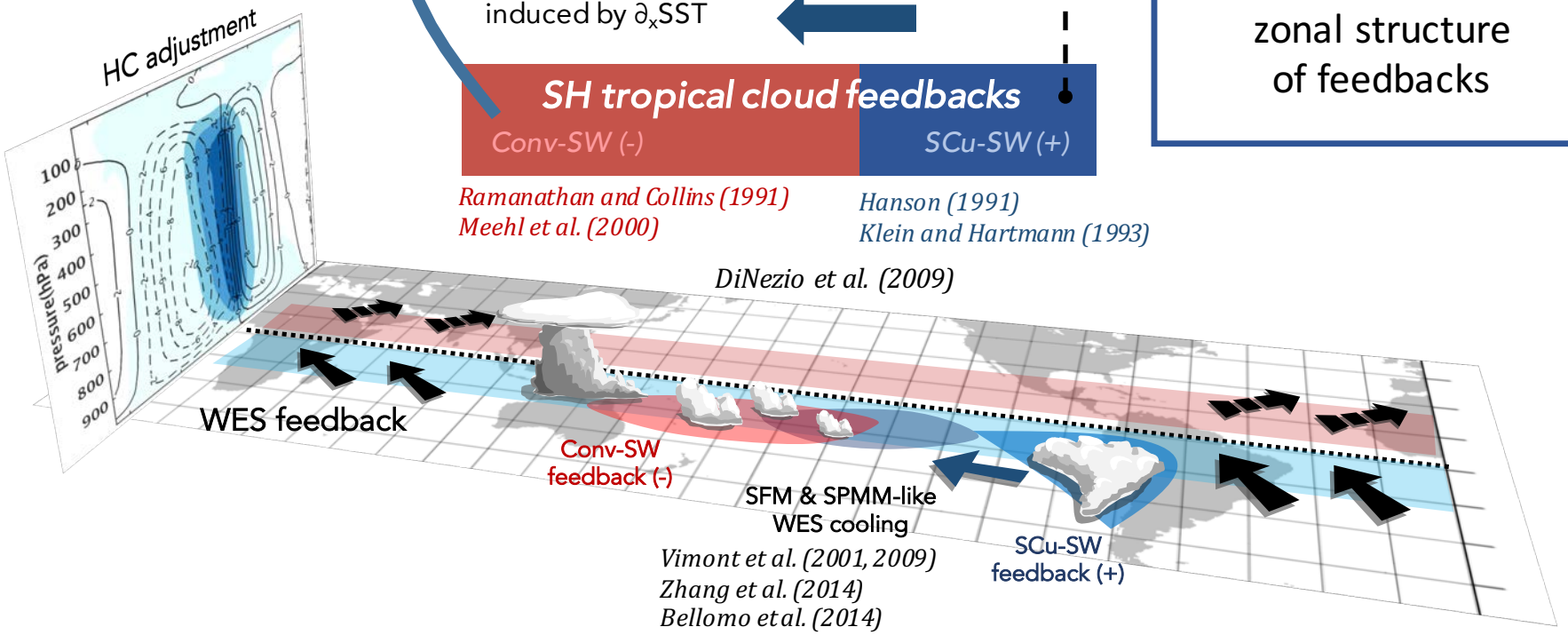
Ramanathan and Collins (1991)
Meehl et al. (2000)

Hanson (1991)
Klein and Hartmann (1993)

meridional structure of feedbacks

Tropical cloud feedback

zonal structure of feedbacks



DiNezio et al. (2009)

Vimont et al. (2001, 2009)
Zhang et al. (2014)
Bellomo et al. (2014)